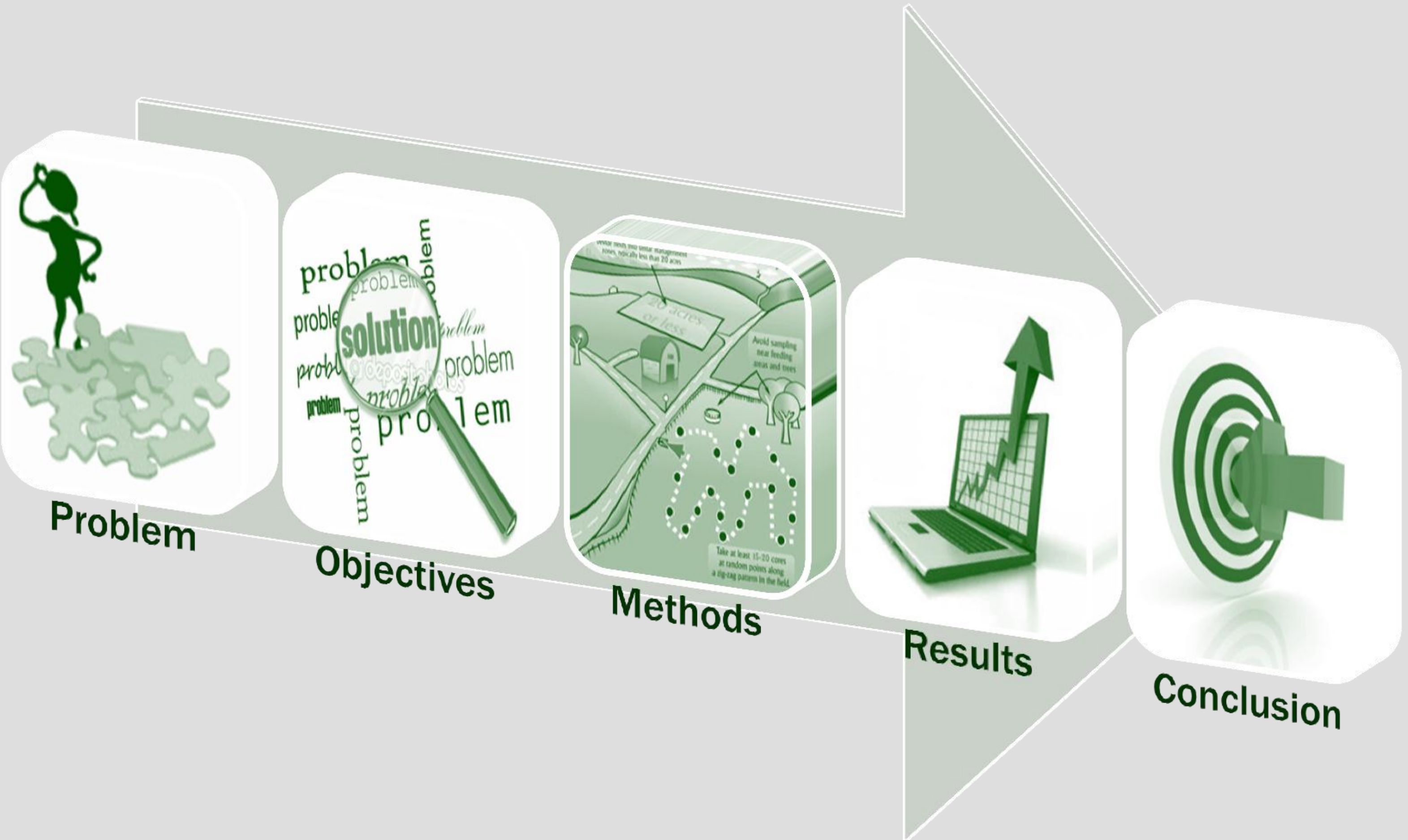
World Congress on Advances in Civil, Environmental and Materials Research, August 25 2012, Seoul, South Korea

NUTRIENT RECYCLING FROM BIO-DIGESTION WASTE AS CHEMICAL FERTILIZER SUBSTITUTES

Céline Vaneeckhaute, Erik Meers, Greet Ghekiere, Frederik Accoe, Evi Michels, Filip M.G. Tack

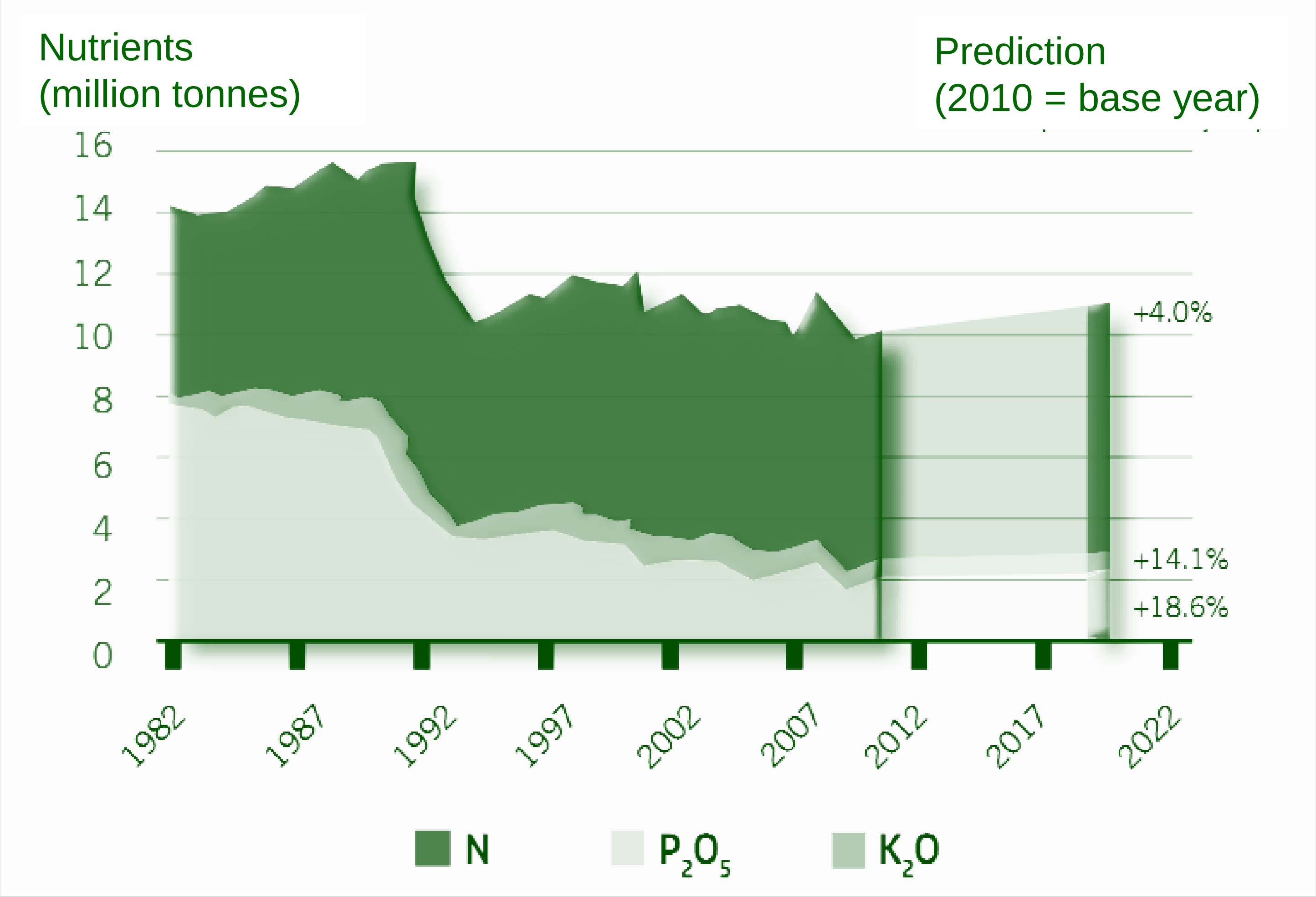
Laboratory of Analytical and Applied Ecochemistry,
Faculty of Bioscience Engineering,
Ghent University, Belgium
Celine.Vaneeckhaute@ugent.be

OUTLINE



PROBLEM STATEMENT

CHEMICAL FERTILIZER USE IN EU27

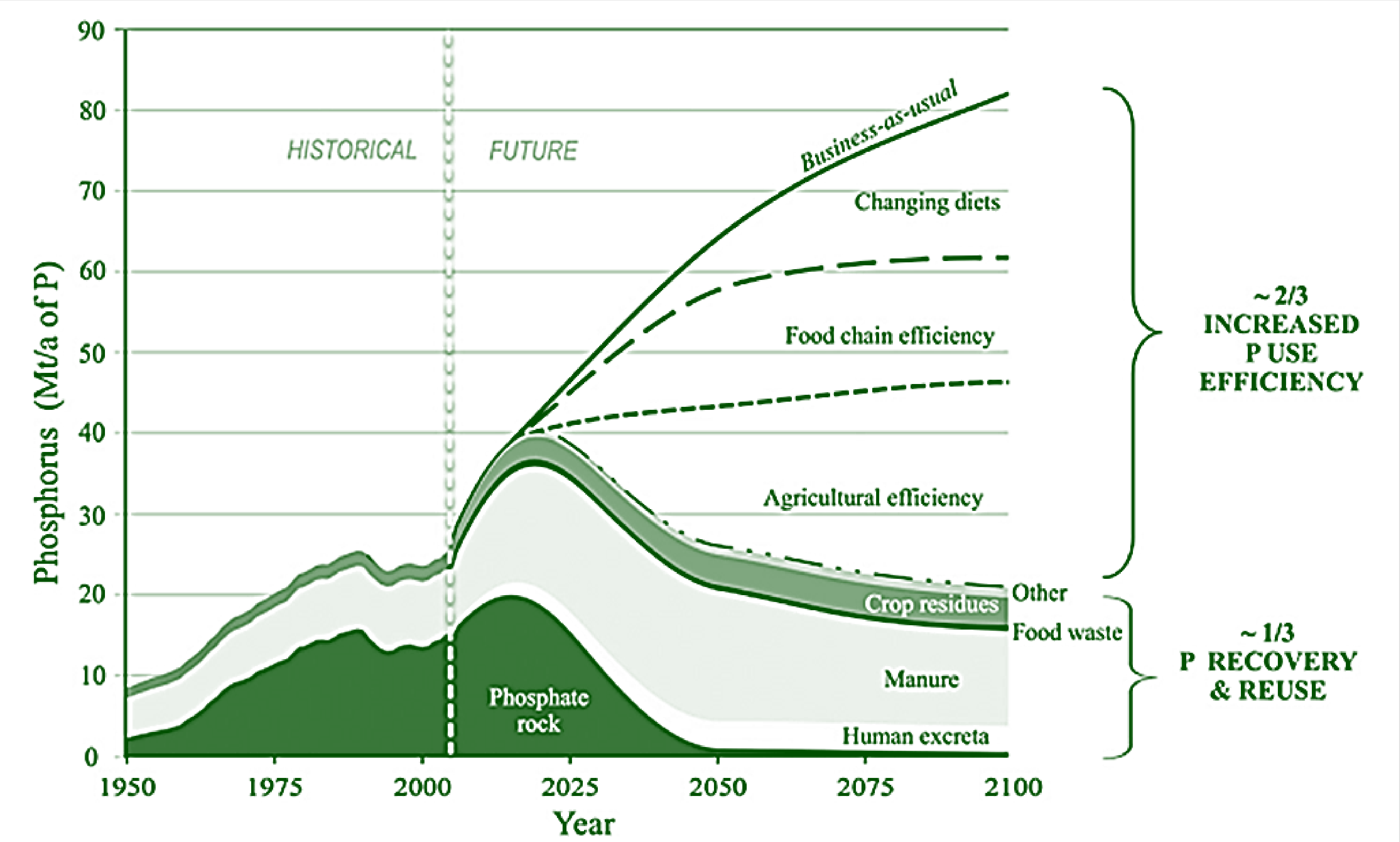


Fertilizers Europe, 2010

ENERGY USE AND COSTS FOR CHEMICAL FERTILIZERS

		N	P_2O_5	K_2O	Unit	Reference
ENERGY	Production	70	7.7	6.4	GJ/ton	Gellings & Parmenter (2004)
	Packing	2.6	2.6	1.8	GJ/ton	Gellings & Parmenter (2004)
	Transport	4.5	5.7	4.6	GJ/ton	Gellings & Parmenter (2004)
	Application	1.6	1.5	1.0	GJ/ton	Gellings & Parmenter (2004)
	Total	78	18	14	GJ/ton	Gellings & Parmenter (2004)
COSTS	Total	1.037	0.956	0.625	euro/kg	Aveve (2011)

NUTRIENT USE VS. DEPLETION



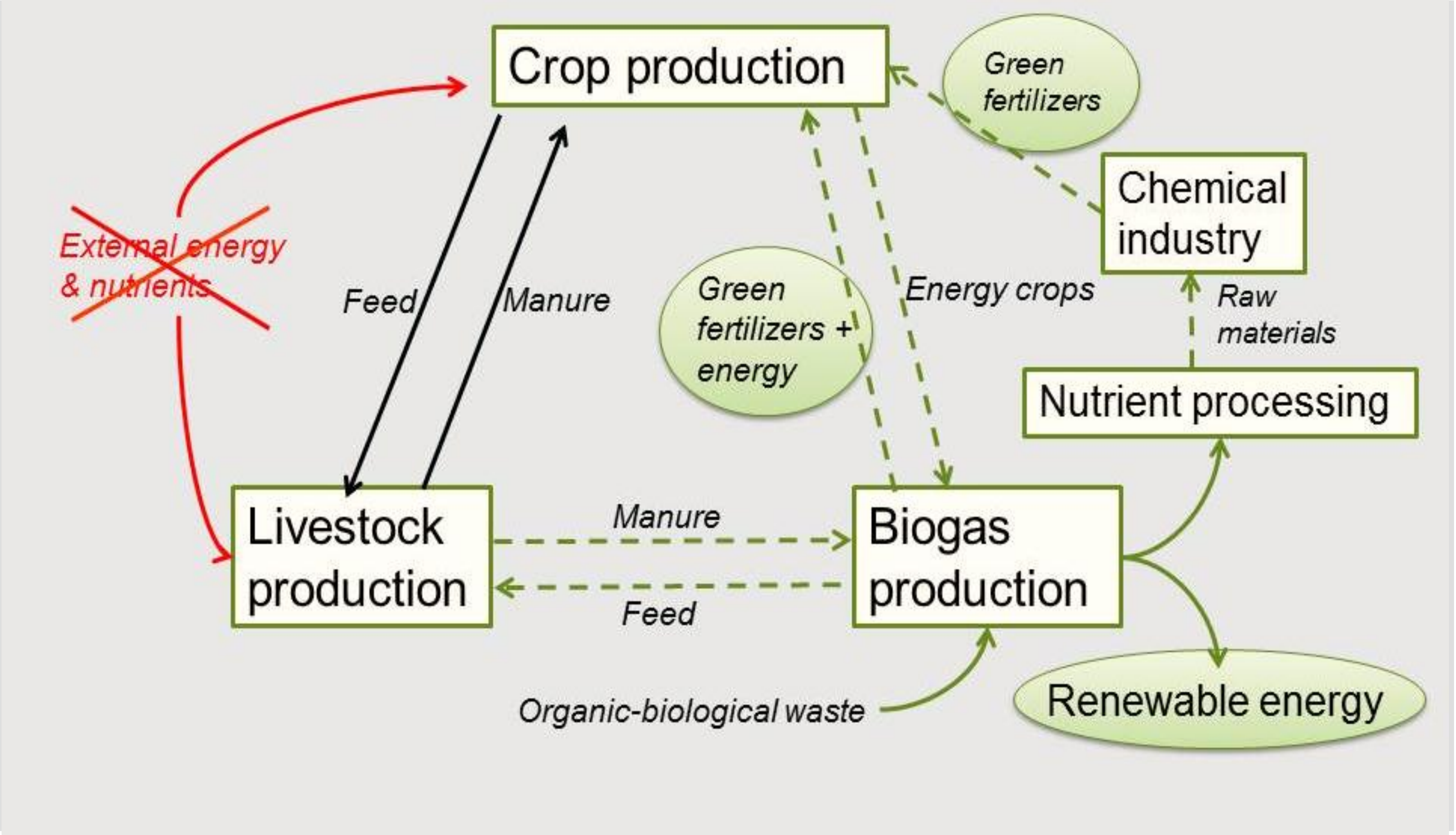
Cordell et al., 2011

NEED FOR A SUSTAINABLE RESOURCE MANAGEMENT !

OBJECTIVES


problem
problem
problem
solution
problem
problem
problem
problem
problem
problem
problem

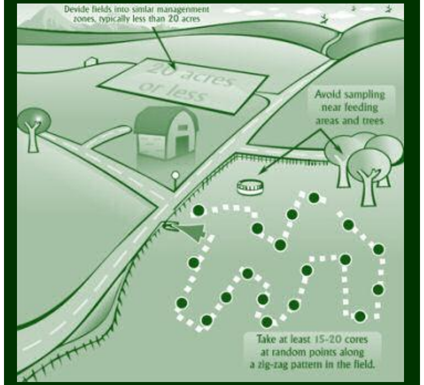
CRADLE-TO-CRADLE NUTRIENT RECYCLING



SPECIFIC GOALS

1. Recuperation of nutrients from bio-digestion waste as green fertilizers
2. Evaluation of the impact on biomass yield and soil quality
3. Economic and ecological analysis

METHODS



Devide fields into simlar managenment
zones, typically less than 20 acres
20 acres
or less
Avoid sampling
near feeding
areas and trees
Take at least 15-20 cores
at random points along
a zig-zag pattern in the field.

FIELD EXPERIMENT WINGENE, FLANDERS

EIGHT FERTILIZATION SCENARIOS

Dosage of effective N and K_2O based on fertilizer analysis and soil advice (150 kg effective N/ha, 80 kg P_2O_5/ha, 180 kg K_2O/ha)

	Chemical Start N[a]	Chemical N[a]	Air scrubber water	Animal manure	Digestate mixture[b]	LF[c] digestate	Chemical K_2O[d]
	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg K_2O/ha
1	25	29	0	96	0	0	78
2	25	0	29	96	0	0	78
3	0	0	54	96	0	0	78
4	25	18	0	0	107	0	29
5	25	0	18	0	107	0	29
6	0	0	43	0	107	0	29
7	25	0	0	84	0	35	33
8	0	0	0	78	0	59	0

[a] ammoniumnitrate (27 % N), [b] Mixture (φ = 0.5) of digestate and liquid fraction of digestate
[c] LF = Liquid Fraction, [d] patentkali (30 % K_2O, 10 % Mg)

FOUR REPLICATIONS

Strip of land			
obj 7	obj 8	obj 2	obj 5
obj 1	obj 4	obj 3	obj 4
obj 2	obj 5	obj 1	obj 6
Strip of land			
obj 3	obj 6	obj 7	obj 8
obj 2	obj 4	obj 7	obj 8
Strip of land			
obj 1	obj 5	obj 3	obj 6
obj 3	obj 6	obj 2	obj 5
obj 7	obj 8	obj 1	obj 4
Strip of land			

FERTILIZER APPLICATION

Boco-trance

SAMPLING OF PLANT AND SOIL

July, September, October (harvest), November (nitrate residue)

PHYSICO-CHEMICAL ANALYSIS

PLANT	SOIL
Yield Fresh & dry weight, N, P, K, Ca, Mg, Na, S, metals Biogas potential	0-30 cm: dry weight, pH-H_2O, pH-KCl, EC, N, NO_3, NH_4, P, K, Ca, Mg, Na, S, metals, Cl^-, plant available nutrients 30-60 cm, 60-90 cm: dry weight, NO_3

RESULTS

VISUAL

June 4 2011

Simultaneous growth

VISUAL

June 4 2011

Drought symptoms

VISUAL

June 19 2011

Plant ±30 cm

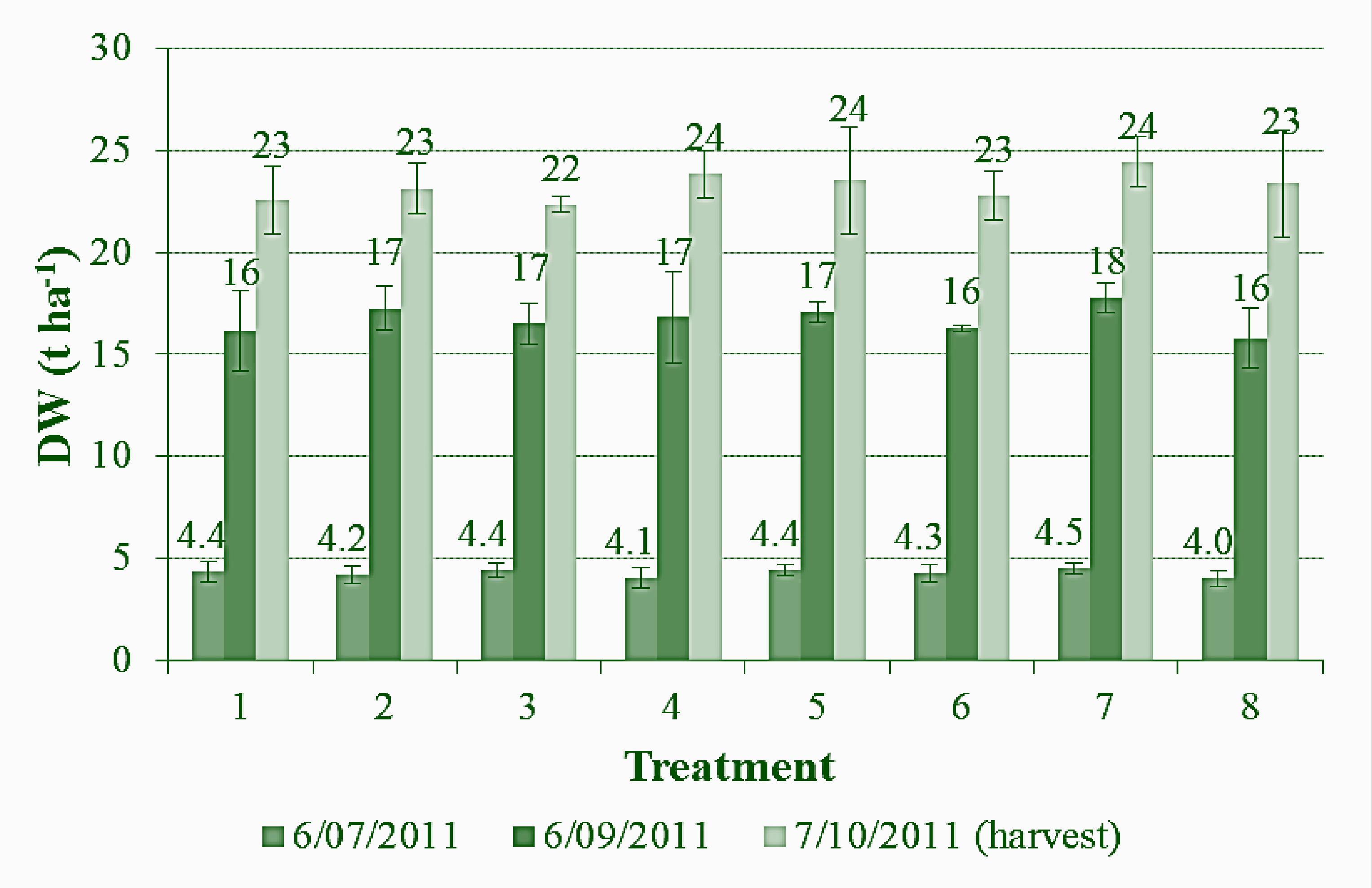
VISUAL

Aug 20 2011

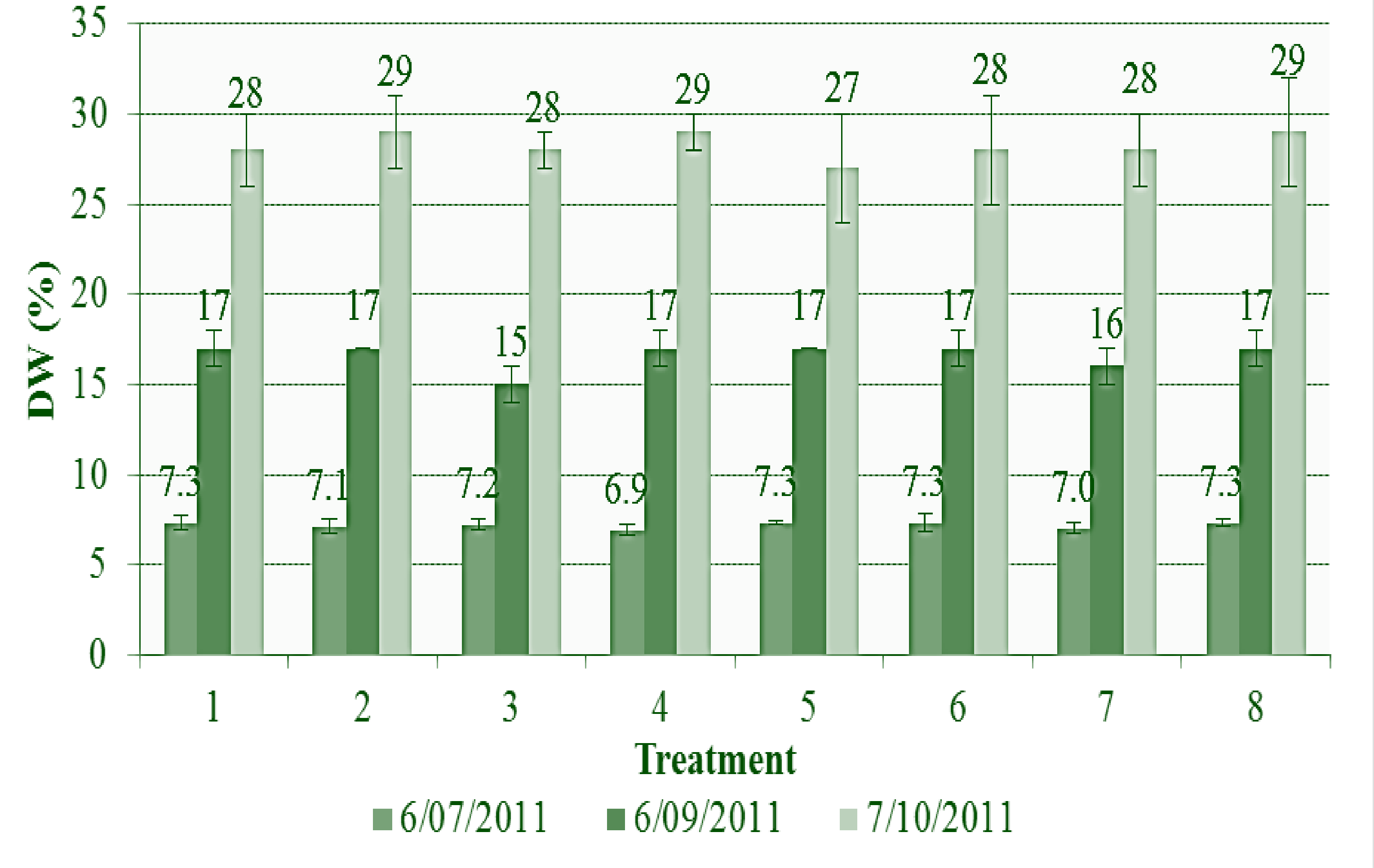
Plant ±3.60 m

Cob formation

DRY WEIGHT BIOMASS YIELD

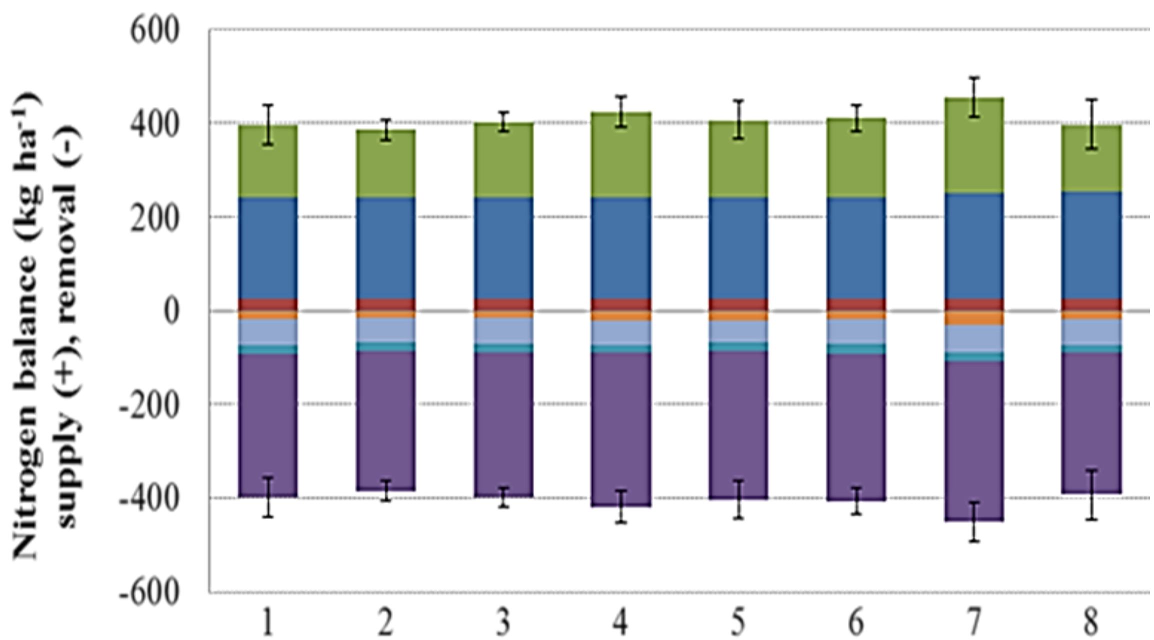


DRY WEIGHT CONTENT



BIOGAS POTENTIAL

Scenario	DW (%)	Residence time (d)	Biogas (Nm^3 ton^{-1} FW)	CH_4 (m^3 ha^{-1})	Energy (GJ ha^{-1})	Electricity (MWh_{el} ha^{-1})	Heat (MWh_{th} ha^{-1})
1	28	42	136	6309 ± 156	200 ± 5	22 ± 1	24 ± 1
2	29	34	143	6536 ± 245	207 ± 8	23 ± 1	25 ± 1
3	28	36	135	6260 ± 232	198 ± 7	22 ± 1	24 ± 1
4	29	39	140	6659 ± 80	211 ± 3	23 ± 0	26 ± 0
5	27	37	131	6536 ± 150	207 ± 5	23 ± 1	25 ± 1
6	28	42	135	6383 ± 384	202 ± 12	22 ± 1	25 ± 1
7	28	41	139	6818 ± 79	216 ± 3	24 ± 0	26 ± 0
8	29	37	140	6558 ± 80	208 ± 3	23 ± 0	25 ± 0



	1	2	3	4	5	6	7	8
Decomposition organic matter	156	145	162	182	165	169	206	142
Manure supply	216	216	216	217	217	217	225	230
Deposition	25	25	25	25	25	25	25	25
Removal with products	-306	-301	-309	-329	-317	-313	-344	-303
Volatilization	-17	-18	-19	-16	-19	-24	-17	-17
Leaching/denitrification subsoil	-58	-53	-56	-53	-47	-52	-60	-55
Denitrification	-17	-14	-16	-21	-21	-18	-31	-19

NITROGEN BALANCE

Modeled with NDICEA

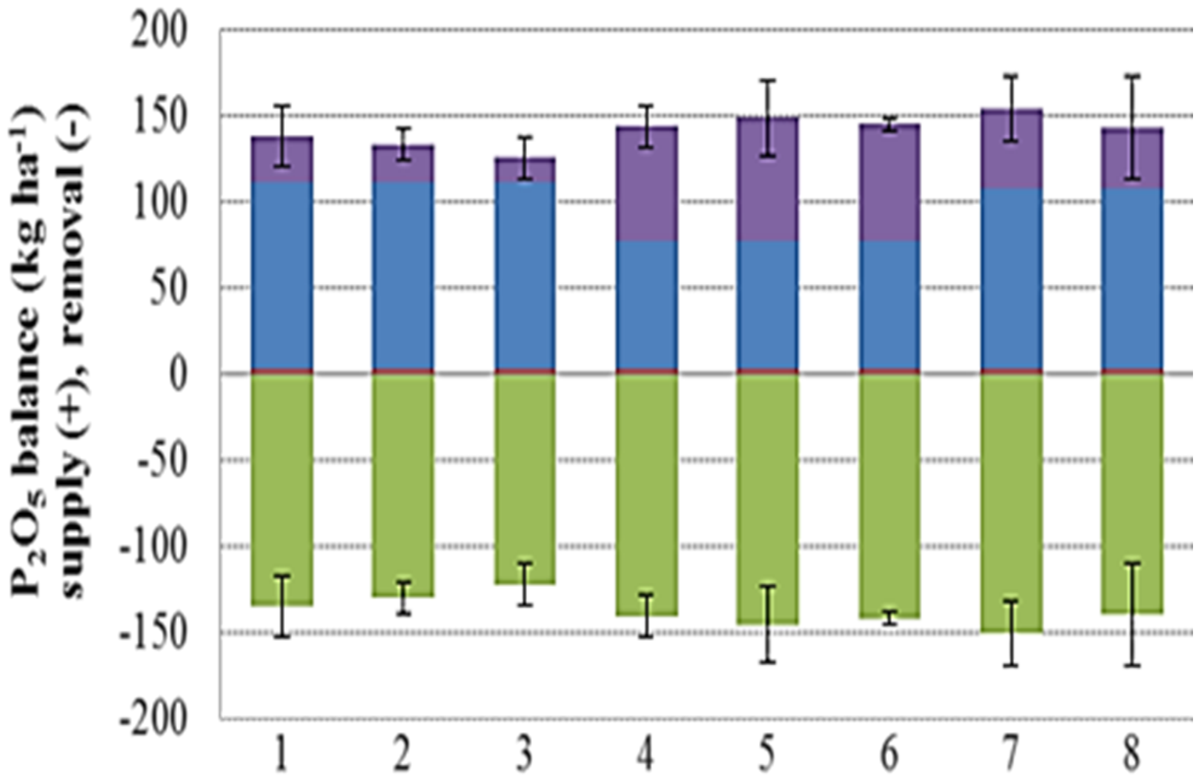
No significant differences (α=0.5)

Demand > supply by manure application

Nitrate leaching lower than reference, except scenario 7

Nitrate residue high in scenario 1,2,3,5 (weather conditions)

PHOSPHATE BALANCE



Calculated deficit	27	22	15	67	72	68	46	35
Manure supply	108	108	108	74	74	74	105	105
Deposition	3	3	3	3	3	3	3	3
Removal with products	-135	-130	-123	-141	-146	-142	-151	-140

Demand > supply in all scenarios

Supply > standard in scenario 1,2,3,7,8 (manure variability)

Uptake soil P higher in scenario 4,5,6

=> Higher soil nutrient use efficiency ?

EIGHT FERTILIZATION SCENARIOS

Dosage of effective N and K_2O based on fertilizer analysis and soil advice (150 kg effective N/ha, 80 kg P_2O_5/ha, 180 kg K_2O/ha)

	Chemical Start N[a]	Chemical N[a]	Air scrubber water N	Animal manure	Digestate mixture[b]	LF[c] digestate	Chemical K_2O[d]
	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg K_2O/ha
1	25	29	0	96	0	0	78
2	25	0	29	96	0	0	78
3	0	0	54	96	0	0	78
4	25	18	0	0	107	0	29
5	25	0	18	0	107	0	29
6	0	0	43	0	107	0	29
7	25	0	0	84	0	35	33
8	0	0	0	78	0	59	0

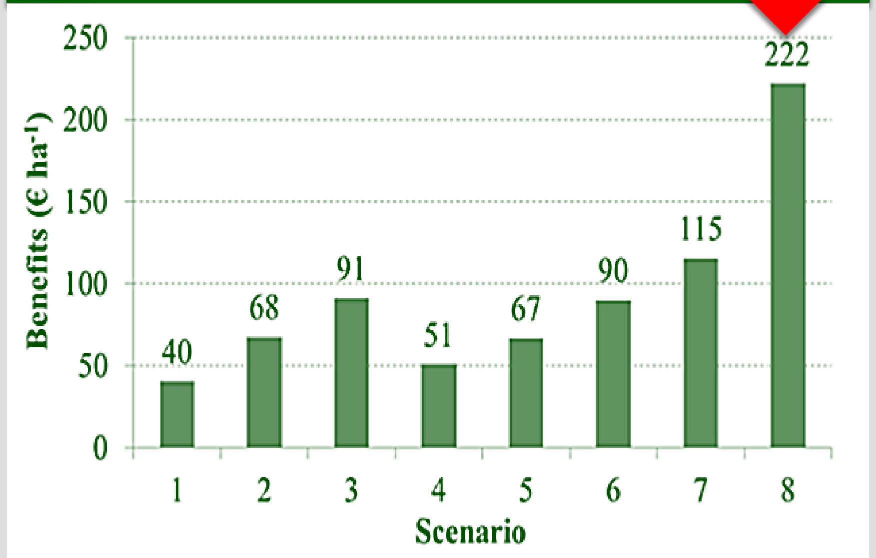
[a] ammoniumnitrate (27 % N), [b] Mixture (φ = 0.5) of digestate and liquid fraction of digestate
[c] LF = Liquid Fraction, [d] patentkali (30 % K_2O, 10 % Mg)

SOIL QUALITY

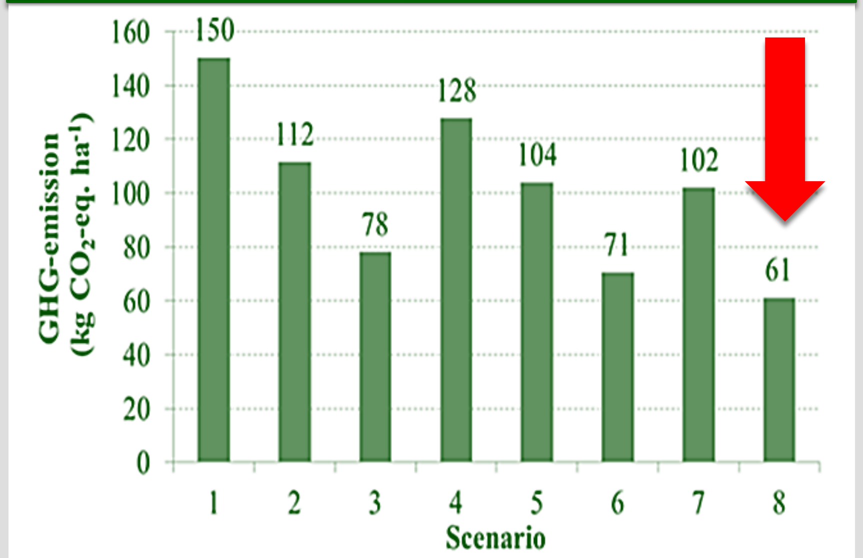
- No significant effect on soil EC, pH-H_2O, pH-KCl, Sodium Adsorption Ratio
- Significantly more organic carbon in scenario 4-8
- High Cu-concentration in all scenarios (historical)

ECONOMIC AND ECOLOGICAL EVALUATION

Benefits (euro/ha)



Greenhouse gas emission ($kg\ CO_2$ eq./ha)



EIGHT FERTILIZATION SCENARIOS

Dosage of effective N and K_2O based on fertilizer analysis and soil advice (150 kg werkbare N/ha, 80 kg P_2O_5/ha, 180 kg K_2O/ha)

	Chemical Start N[a]	Chemical N[a]	Air scrubber water N	Animal manure	Digestate mixture[b]	LF[c] digestate	Chemical K_2O[d]
	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg K_2O/ha
1	25	29	0	96	0	0	78
2	25	0	29	96	0	0	78
3	0	0	54	96	0	0	78
4	25	18	0	0	107	0	29
5	25	0	18	0	107	0	29
6	0	0	43	0	107	0	29
7	25	0	0	84	0	35	33
8	0	0	0	78	0	59	0

[a] ammoniumnitrate (27 % N), [b] Mixture (φ = 0.5) of digestate and liquid fraction of digestate
[c] LF = Liquid Fraction, [d] patentkali (30 % K_2O, 10 % Mg)

CONCLUSIONS AND PERSPECTIVES

CONCLUSIONS

Recycling of nutrients from bio-digestion waste derivatives in agriculture can:

- create sustainable substitutes for chemical fertilizers
- increase the soil nutrient use efficiency
- result in significant economic and ecological benefits

PERSPECTIVES

- Stimulation of green fertilizer use in European legislation

- Validation of results in the longer term and for different soil types

  (2012-2013)

THANK YOU FOR THE ATTENTION

QUESTIONS ?